EFFECT OF SAWDUST POWDER - OIL PALM SHELL (OPS) ASH MIXTURE ON COMPRESSIVE STRENGTH OF OPC MORTAR

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Report submitted in partial fulfilment of the requirements
for the award of the degree of
B. Eng (Hons.) Civil Engineering

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UNIVERSITI MALAYSIA PAHANG

JUNE 2014

ABSTRACT

There is an enormous amount of waste materials being disposed due to the growth of industrialization and urbanization nowadays. The high demand of cement in construction field has posed the researches to make use of these waste materials to serve as partial substitute material in cement. This study will be conducted to evaluate the performance of sawdust and oil palm shell (OPS) on the mechanical properties of Ordinary Portland Cement (OPC) mortar. The aim of this research is to investigate the compressive strength, modulus of elasticity and workability of the cement mortar with various percentages of sawdust powder- OPS ash. Four types of mix design were prepared with the constant w/c of 0.40 and sawdust powder-OPS ash content of 1%, 2%, 3% and 4% are replaced the amount of cement respectively. 50% of fine sand is also required to be placed in the mixture so that the exact strength value can be obtained during compressive testing. Curing was considered at the age of 7, 28, and 56 days. From the test, the slight increase of the strength of concrete with cement replacement showed when age increase. These results indicate that sawdust powder-OPS ash can be applied to produce cement mortar with acceptable compressive modulus elasticity. This is a promising method with a friendly environment and economical effect.

ABSTRAK

Terdapat sangat banyak sisa-sisa bahan terbiar dan dibuang disebabkan oleh pertumbuhan dan pembandaran yang pada masa kini. Permintaan simen yang tinggi dalam bidang pembinaan telah memberi penyelidikan untuk menggunakan sisa bahan-bahan ini untuk diguna sebagai bahan separa gantian dalam simen. Kajian ini akan dijalankan untuk menilai prestasi serbuk habuk papan dan tempurung kelapa sawit (OPS) pada sifat-sifat mekanik OPC mortar. Tujuan kajian ini adalah untuk menyiasat kekuatan mampatan, modulus keanjalan, kebolehkerjaan simen mortar dengan pelbagai peratusan habuk papan-OPS abu. Terdapat empat jenis reka bentuk campuran telah disediakan dengan nisbah air, w / c sebanyak 0.40 dan serbuk habuk papan - OPS kandungan abu sebanyak 1% , 2% , 3% dan 4% digantikan jumlah simen masing-masing. 50% daripada pasir halus juga diperlukan untuk diletakkan di dalam campuran supaya nilai kekuatan yang tepat boleh diperolehi semasa ujian mampatan. Pengawetan dianggap pada usia 7 , 28 dan 56 hari. Dari ujian, peningkatan sedikit kekuatan konkrit dengan penggantian simen menunjukkan apabila umur meningkat. Keputusan ini menunjukkan bahawa serbuk habuk papan - OPS abu boleh digunakan untuk menghasilkan simen mortar dengan kekuatan yang boleh diterima. Ini adalah kaedah yang menjanjikan dengan persekitaran yang mesra dan kesan ekonomi.

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LIST OF ABBREVIATIONS

CKD	Cement Kiln Dusts
FA	Fly Ash
OPC	Ordinary Portland Cement
OPS	Oil Palm Shell
POFA	Palm Oil Fuel Ash
PKSA	Palm Kernel Shell Ash
RHA	Rice Husk Ash
SDA	Sawdust Ash

LIST OF SYMBOLS

CO_2	Carbon Dioxide
$Ca(OH)_2$	Calcium Hydroxide
kg	Kilogram
mm	Milimeter
%	Percentage

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CHAPTER 1

INRODUCTION

1.1 BACKGROUND

Ordinary Portland Cement (OPC) is nowadays being widely used in the construction field as the basic constituent material for the production of concrete, mortar, and cement grout. Due to the increase of cement demand, several researches have been executed to explore for the substitute's material as a replacement of Ordinary Portland Cement. Wastes that produced by the industries such as slag, silica fume, and fly ash are applied as the mean of admixture to reduce the amount of cement required. For instance, fly ash is used as a substitute material for Portland cement in concrete due to the ability to increase the workability with lower water demand, durability and environmental benefit (Niemuth and Mark, 2012). While Khanna (2012) has done his research on utilized the Cement Kiln Dusts (CKD) to replace the application of cement and study the characteristics of the material.

There are also agricultural wastes such as sawdust ash (SDA), oil palm shell (OPS) ash and rice hush ash used to treat as pozzolanic material in concrete. Pozzolana is a type of materials that only show the cement properties when there are in fine and moist condition (Marthong, 2012). According to Larbi, Fraay, and Bijen (1990), pozzolana materials which consist of large amounts of silicon dioxide will accelerate the early state of hydration of OPC. Sawdust powder is the fine particle form of timber and is produced from milling process of boards or planks. Based on the experiments conducted by Raheem, Olasunkanmi, and Folorunso in year 2012, the compressive strength of concrete is increased with age but lower when the amount of SDA is raised. Therefore, cement paste will obtain the optimum strength only when the amount of SDA adds 5%. Oil Palm

Shell (OPS) is produced from the milling process in agriculture or farming factory which performing as a benefit additive to be used in the construction phase. Research conducted by Gungat, Putri and Makinda (2013) shows the utilization of OPS in improving the shear strength of subgrade. Application of OPS as the replacement of cement will increase the workability of concrete with zero segregation but decreases in compressive strength (Tay and Show, 1995). Apart from this, Shafigh, Jumaat, Mahmud, and Alengaram (2013) took OPS as the replacement of coarse aggregates to test on the strength of lightweight concrete.

In this paper, the waste materials mixture has been used to develop acceptable construction materials. The effect of sawdust powder -OPS ash mixture on compressive strength of OPC mortar mixture has been investigated to improve OPC modulus elasticity of OPC.

1.2 PROBLEM STATEMENT

In this modern era, more and more conventional buildings require to be constructed due to the increase in population of our country. This phenomenon ultimately increased the demand for the use of cement especially Ordinary Portland Cement (OPC) in the construction industry. Thus, there is essential to seek for the additive cementitous materials to partially replace the content of cement. Malaysia is popular in producing and exporting palm oil to others country. After the extraction of palm oil from palm oil fruit, the other part of palm oil tree such as bunches and shell, fiber will be dumped. Tay and Show (1995) in their research state that about 5% of the ash will be decomposed in landfill after the combustion of the shell or fiber is carried out for the manufacture of fuel. Oil Palm Shell (OPS) ashes which are very fine in size will be blown by wind and cause the formation of smog that threatens human health. The OPS ash which shows high alkaline properties is not suitable to treat as fertilizer. Same cases as sawdust which is the waste materials being dispose in timber industry when the production process of the boards is conducted. Thus, due to the serious disposal of waste from industrial and agricultural residue, proper treatment and consideration on the wastes should be taken in order to avoid environmental contamination and it will be more economic benefit if we make use of these wastes as the substitute of cement.

The formation of cement will cause the emission of carbon dioxide, CO_2 to be released to the atmosphere. This phenomenon is a reason for occurrence of the global warming. Therefore, the utilization of these wastes is necessary to cure the negative impact due to the cement production. Both of the oil palm shell ash and sawdust powder compose of high silicon dioxide which have the ability to resist the sulfate attack found in soils, seawater and groundwater. Jaturapitakkul, Kiattikomol, Tangchirapat and Saeting (2007) in their result show that Palm Oil Fuel Ash (POFA) could enhance the sulfate resistance of concrete in term of expansion and deduction in compressive strength. Their finding is supported by Awal and Hussin in year 1997 state that POFA can create concrete with high strength, 100MPA at 90 days.

1.3 RESEARCH OBJECTIVES

The objectives of this research are:

i. To investigate the effect of sawdust powder- OPS ash mixture on the compressive strength of the cube on 7 days, 28 days and 56 days.
ii. To analyze the modulus elasticity of OPC mortar mixture with the replacement of sawdust powder- OPS ash.
iii. To verify the workability of OPC mortar that has replaced with sawdust powder- OPS ash in different percentages.

1.4 SCOPE OF STUDY

This study is, to determine the behaviors of the sawdust powder- OPS ash as partial replacement of cement on the OPC mortar mixture. In experimental work, pure cement paste should prepare for compressive testing but in fact, cement paste without sand does not give exact strength value because of trapped air in it. These trapped air voids induce big scattering in test results. Therefore, 50% of very fine sand has been added to cement-additive to avoid this mistake. The total 15 samples of cubes will be prepared with the dimension of 100mm × 100mm × 100mm, to measure compressive strength, modulus elasticity, and workability of the specimens. The mix design has been made based on the weight ratio of cement, water, sawdust powder, oil palm shell (OPS)

ash and fine sand. There are four types various percentages of sawdust powder-OPS ash was prepared that are 1%, 2%, 3% and 4%. The water-cement ratio of 0.40 will be added to the mix of samples respectively. The entire samples are then kept in water for 7 days, 28 days, and 56 days for curing process to take place. The engineering properties test will be conducted after curing period.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Various previous studies or researches that related to this study will be theoretical performed in this chapter. There will be three subsection topics of the chapters which are Ordinary Portland Cement (OPC), cement replacement and the properties of cement mortar.

2.2 ORDINARY PORTLAND CEMENT (OPC)

Ordinary Portland Cement (OPC) is the cement that commonly used for the production of concrete, mortar and cement grout in construction industries to implement the construction projects given by the clients or owners who responsible to fulfill the demand of society. OPC is created by heating absolutely high temperature of limestone and clay in a kiln to form Portland cement clinker. Consequently, clinker will be chilled and grind into fine powders which known as Portland cement. However, huge amounts of carbon dioxide, CO_2 will be emitted to the atmosphere during the production of Portland cement. According to Sooraj (2013), 1 ton of cement production will emit roughly 5% of carbon dioxide to the atmosphere and this will increase the probability of global warming to occur. This phenomenon creates serious pollution to the air and ultimately threatens human life.

Hence, there are many researchers starting to investigate and study the effect of using the natural waste materials to replace largely cement used in construction industries. For instance, Jain (2011) compares the effect between pozzolanic (marble-dust) and non-

pozzolanic material (Rice Husk Ash) to the action of hydration and mechanical properties of OPC. Physical and chemical properties of Portland cement are then analyzed as shown in Table 2.2. Olutoge, Quadri and Olafusi (2012) had conducted a research on using Palm Kernel Shell Ash (PKSA) as the substitute of Portland cement in producing concrete to study the effect of PKSA on the strength of OPC concrete. Other than that, agriculture or industries wastage such as Palm Oil Fuel Ash, (Jaturapitakkul et al., 2007), fly ash, (Christy & Tensing, 2010), sawdust ash (Raheem et al., 2012) and coconut shell ash (Utsev and Taku, 2012).

Table 2.1: Physical and Chemical Properties of OPC 43 Grade (Jain, 2011)

Properties	OPC (43 G)
Specific gravity (kg/cm^3)	3.14
Insoluble residue (%)	1.3
Alkalies (%)	0.35
SO_3 (%)	2.10
Chloride (%)	0.012
LOI (%)	1.51
Surface area (m^2/kg)	308
Silica content (%)	20.6
CaO (%)	60.2
Magnesia (%)	1.4
Fe_2O_3	-
Al_2O_3	-

2.2.1 Cement Mortar

Cement mortar is the product of the mixture of water, fine sand, and Portland cement. Mortar is characterizing as fresh concrete due to the absent of course aggregates. It is specifically used in construction firm to provide a relatively strong bond between bricks or blocks to the wall and also to fill the gaps between them. Workability of mortar is generally depends on the amount of water added to the mixture. Cement mortar is normally selected to carry out testing instead of cement paste as it will prompt more accurate results compared to concrete. The present of fine sand in the mixture of mortar will give exact strength value when compressive strength test is conducted.

Several tests can be run by using cement mortar as it can perform real condition when admixture is added compared with that of using cement paste or concrete. Christy and Tensing (2010) had add fly ash as the partial replacement of cement in order to study the effect of this material on the compressive strength of mortar. The purpose of this study is similar to the finding conducted by Islam M.M and Islam M.S in the same year where the strength action of fly ash mortar is probed. Pozzolanic materials which are Rice Husk Ash (RHA), Palm Oil Fuel Ash (POFA), and Fly Ash (FA) have the ability to enhance the resistance to chloride penetration of the mortar (Chindaprasirt, Rukzon and Sirivivatnanon, 2008).

Besides, Bilim (2012) has examined the durability of cement mortar using Clinoptilolite as the cement replacement substances. Fineness of the cement replacement materials is considered as an important factor to improve the compressive strength and resist the sulfate attack of soils or groundwater towards mortar (Tangchirapat, Jaturapitakkul and Kiattikomol, 2009). Elinwa and Abdulkadir (2011) also illustrate the strength and durability of SDA in mortar against sulfate and acid resistance.

2.3 CEMENT REPLACEMENT

Cement replacement materials are typically the natural waste material or industrial waste products that can be used to substitute some of the Portland cement in concrete mixer. Several types of waste materials that pose pozzolanic properties had been investigated to replace the use of cement in construction industries so that the negative impact on the environment due to the emission of carbon dioxide, CO_2 during the production of cement can be reduced. Cement substitutes which establish as pozzolan tend to behave like Portland cement during hydration and curing process.

Pozzalanic materials normally have the capability to release silica which chemically react with calcium hydroxide, $Ca(OH)_2$ to form cementitious product, C-S-H that owning similar properties as cement (Ransinchung & Kumar, 2010). This explanations are consistence with the studies conducted by Elinwa and Abdulkadir (2011) who in their experiment found that the amount of $Ca(OH)_2$ released during hydration process of cement with SDA are lesser when compare with the one without SDA content after 90 curing days. This condition consequently causes the production of C-S-H content

to be higher in SDA mortar than Ordinary Portland mortar. Besides, pozzolan have the properties to resist sulfate attack, found in soils, seawater, and groundwater.

Concrete with cement replacement material substitute the amount of cement is said to be more durable than the one with only Ordinary Portland cement. Several studies have been lead using different pozzolanic products to replace and mitigate the use of cement. Kumar, Rao and Sai (2013) presented good viewpoints in partially replacing the cement with quarry dust in concrete. Utsev and Taku in year 2012 successfully applied coconut shell ash as partial replacement of Ordinary Portland cement. The utilization of fly ash as an excellent pozzolanic material has confirmed by many researchers (Zachar, 2011; Christy and Tensing, 2010; Mukherjee, Mandal and Adhikari; 2012). Meanwhile, numerous studies have attempted to demonstrate the effect of Palm Oil Fuel Ash (POFA) as cement replacement in concrete and mortar (Sooraj, 2013; Awal and Hussin, 1997; Awal and Shehu, 2011).

Although there are researches that examined the effect of either sawdust or Oil Palm Shell (OPS) Ash as the cement replacement material and giving encouraging results, the mixture placing both sawdust and OPS Ash combination has not been considered yet. The cement replacement materials that involved in this study are the combination of sawdust and Oil Palm Shell (OPS) Ash. The influence of these combination materials on the compressive strength of cement mortar is then investigated.

2.3.1 Sawdust

Sawdust is a very fine particle of wood that produced from the milling process which normally involves cutting, grinding, and sanding of boards or planks. Nowadays, sawdust is useful in serving as particleboard, mulch, domestic fuel, or briquette. The weight of sawdust concrete is only slightly heavier than the normal weight of concrete and it will be not flammable if appropriate cement-sawdust ratio is mixed (Marthong, 2012). However, these materials have been largely discharged in landfill due to the development of timber and wood industries for the activity such as furniture manufacture. Generally, sawdust that typically produced from the bark of hardwoods will be more than softwoods or others part of tree. About 5-10% of sawdust will be created in wood sawing process (Turgut and Algin, 2006). The huge amount of sawdust generated had

consequently influenced the environment of our country. Therefore, it is vital to make use of this waste product in a more effective and beneficial way. Treating sawdust in the production of concrete in construction industries has exhibited an economical technique to overcome the waste disposal problem and consequently solve the limited natural resources issues (Mageswari and Vidivelli, 2009).

Sales, Souza and Almeida (2011) investigated the effect of combination of water treatment sludge and sawdust on the mechanical properties of concrete. They concluded that with the present of those composite materials, concrete produced tend to have lower strength compare with the reference concrete. High percentage of water absorption is observed when those composite materials are applied in concrete. However, they proved that the combined water treatment sludge and sawdust display good binding to mortar matrix seen no cracking was detected in the concrete.

There is another study that Aliu and Daramola consume sawdust as alternative binder for concrete. Positive result had displayed by replacing cement with sawdust only in the content of sawdust not more than 10%. This finding specified that the optimum strength obtained is still acceptable to be applied in lightweight structure. Nowadays, sawdust is still not widely used in concrete but it can be made to apply in certain wall and floor (Marthong, 2012).

Many of the researchers have substitute sawdust ash (SDA) which pose the pozzolanic behavior for making concrete in construction industries. The potential of SDA as a good pozzolan is confirmed by Raheem et al,. 2012) stated in their research that 5% of SDA is most suitable content to replace cement in concrete. The workability of SDA concrete is decreasing with the increase of SDA replacement. Higher water demand is required for the SDA concrete to achieve better workability due to the present of silica in the concrete mixture. This outcome is in agreement with Marthong's (2012) finding which described that it is necessary for SDA mixes to request more water content so that better workability can be performed. On the other hand, Elinwa and Abdulkadir (2011) had substituted SDA as the part of cement in order to explore the durability and compressive strength of cement mortar. This finding reveals that 10% of SDA is the

appropriate value to obtain maximum strength. SDA mortar also has the ability to resist the attack of sulfate and acid which will affect the corrosion of reinforcement in concrete.

Tyagher, Utsev and Adagba (2011) defined sawdust ash as a pozzolana to replace OPC and display the chemical properties of SDA as below:-

Table 1.2: Chemical properties of Sawdust Ash (Tyagher, et al., 2011)

Constituents	% by weight
SiO_2	67.95
AL_2O_3	4.29
F_2O_3	2.15
CaO	9.47
MgO	5.84
MnO	0.01
Na_2O	0.06
K_2O	0.11
P_2O_5	0.46
SO_3	0.56

2.3.2 Oil Palm Shell (OPS) Ash

Oil palm industries are widely developed in Malaysia due to the highly demand of oil produce for exportation to others countries. Based on Amiruddin (1998), about 2.6million tones of OPS are annually produced in our country. Oil Palm Shell (OPS) is the solid agriculture waste deposed from oil palm industries after the oils are completely extracted from the oil palm fruits. OPS or known as Palm Kernel Shell (PKS) is the outer hard endocarp of oil palm seed that cover the palm kernel. Several researchers have treated OPS as the lightweight aggregates in producing better quality of lightweight concrete (Basri, Mannan and Zain, 1999; Shafigh et al., 2012; Daneshmand and Saadatian, 2011).

Similar as Palm Oil Fuel Ash (POFA), Oil Palm Shell (OPS) Ash is a waste substantial discharged from oil palm mills after shells are burnt in 800-1000°C to produce

steam for the mean of fuel. Approximately 5% of ashes are released in landfills after the combustion process (Tay and Show, 1995). This situation created a growth of serious waste disposal issue in our country as the ashes are light in size and easily carried by the wind cause of its small particular size and subsequently bring health hazard to human life. In order to minimize this problem and pollution, proper action should be taken into consideration.

Oil Palm Shell (OPS) Ash or Palm Kernel Shell Ash (PKSA) is utilized in the experiment conducted by Olutoge et al., (2012) to determine the effect of this waste material on the strength behavior of concrete. PKSA which pose pozzolanic properties has the potential to act as cement replacement material in enhancing the strength and durability of concrete. However, only small amount of PKSA is suitable to substitute in cement content so that better performance of concrete can be obtained. The chemical properties of PKSA and OPC are shown in table below:-

Table 2.2: Chemical properties of PKSA (Olutoge et al., 2012)

Chemical Composition (%)	OPC	PKSA
SiO2	22.13	54.810
Al2O3	3.74	11.4
Fe2O3	2.97	0.362
CaO	63.36	8.786
MgO	2.58	6.108
K2O	0.52	6.254
True Density (g/cm3)	2.97	2.60

Nowadays, many of the previous researches had substitute Palm Oil Fuel Ash (POFA) as the supplementary cementing material in concrete or mortar and examined various properties toward it. Awal and Hussin in 2011 concentrated on the action of POFA in decreasing the heat of hydration of concrete and positive result is shown when compared to OPC concrete. Jaturapitakkul et.al (2001) also in their studies replaces cement with 10%, 20%, and 30% of POFA with different particle size to investigate the potential of POFA to resist sulfate attack.

Table 2.3: Physical and chemical composition of OPC and POFA (Awal and Hussin, 2011).

Tests	OPC	POFA
Physical properties		
Fineness - Sp. surface area (m^2/kg)	315	520
Soundness – LeChatelier method (mm)	1	1
Specific gravity	3.28	2.22
Chemical composition (%)		
Silicon dioxide (SiO_2)	20.20	43.60
Aluminum oxide (Al_2O_3)	5.70	11.40
Ferric oxide (Fe_2O_3)	3.00	4.70
Calcium oxide (CaO)	62.50	8.40
Magnesium oxide (MgO)	2.60	4.80
Sulphur trioxide (SO_3)	1.80	2.80
Sodium oxide (Na_2O)	0.16	0.39
Potassium oxide (K_2O)	0.87	3.50
Loss on ignition (LOI)	2.70	18.00
28-day Strength activity index with OPC	--	112

2.4 PROPERTIES OF CEMENT MORTAR

Numerous studies related to cement replacement materials have been examined in order to substitute the large consumption of cement in the production of concrete and mortar and subsequently influenced the properties. Several researches established that many of the waste products can use as pozzolanic materials with the present of silicon dioxide which can pose advantages to improve the strength and durability of mortar or concrete Karim, Zain, Jamil and Islam (2011). For instance, Ketkukah and Ndububa (2006) substitute Groundnut Husk Ash in cement content and examined the properties of the mortar. Solid wastes such as fly ash and blast furnace slag are the most common cementitious material selected to use in replacing the amount of cement use in production of concrete. Besides, agro-waste like Rice Husk Ash (RHA), Oil Palm Fuel Ash (OPFA), Palm Kernel Shell Ash (PKSA), and others are also selected to substitute the utilization of cement in construction firms.

2.4.1 Compressive Strength

Compressive strength is the main properties of concrete and cement mortar as they are directly associated with the structure of the hardened cement paste. This property can be affected by several factors which are hydration process, w/c ratio, degree of compaction, fineness of the cement used and the volume of air void in the mixture.

There are also researchers who substitutes Sawdust Ash (SDA) which the sawdust is burned in high temperature for fine aggregates or cement in concrete. Raheem et al. (2012) indicated that the compressive strength of SDA concrete decrease with increasing percentage of SDA to be replaced. They conclude that the strength obtains after SDA added was slow at the early curing stage as the result showed a low value of strength at 3 and 7 days. Yet, the control still appears the highest result compare with the others that SDA is replaced with cement. Starting from 28days until 90days, the compressive strength seems to increase to 5%, 10%, 15%, 20%, and 25% of SDA replacement respectively. This situation explained that during hydration of cement, calcium hydroxide which released will react with the SDA to form C-S-H gel that pose binding properties. However, replacement of cement by SDA will require higher water demand to improve the strength of concrete or mortar.

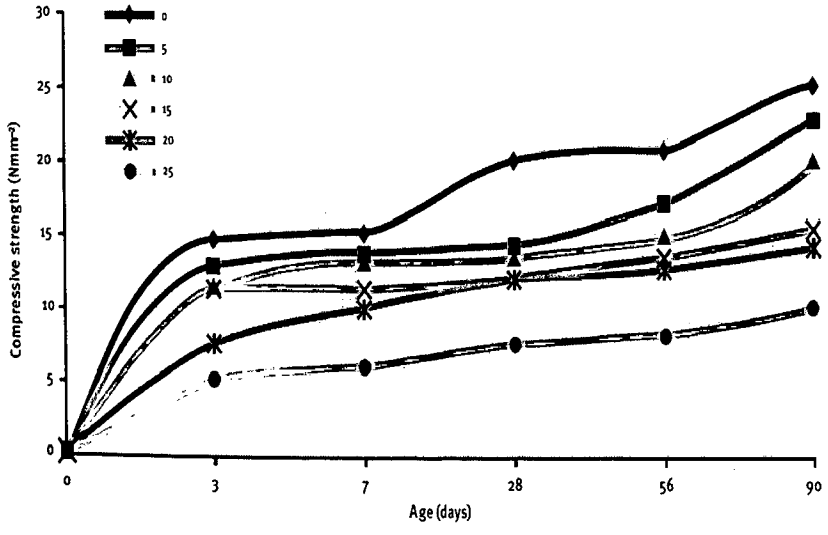

Figure 2.1: Compressive strength against curing period of SDA concrete (Raheem, et al, 2012)